

Managing the Bullwhip Effect in Multi-Echelon Supply Chains

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Abstract

This editorial article presents the bullwhip effect which is one of the major problems faced by supply chain management. The bullwhip effect represents the demand variability amplification as demand information travels upstream in the supply chain. The bullwhip effect research has been attempting to prove its existence, identify its causes, quantify its magnitude and propose mitigation and avoidance solutions. Previous research has relied on different modeling approaches to quantify the bullwhip effect and to investigate the proposed mitigation/avoidance solutions. Extensive research has shown that smoothing replenishment rules and collaboration in supply chain are the most powerful approaches to counteract the bullwhip effect. The objective of this article is to highlight the bullwhip effect avoidance approaches with providing some interesting directions for future research.

The Bullwhip Effect

The variability of replenishment orders tends to increase as one moves up the supply chain, causing the bullwhip effect (Figure 1). The presence of the bullwhip effect in supply chains leads to severe consequences such as stock outs, low service level, and extra transportation and capacity costs. Lee et al. [1] identified five operational causes of the bullwhip effect: demand signal processing, lead-time, order batching, price fluctuations and rationing and shortage gaming. Extensive modeling studies have quantified the impact of these causes utilizing three modeling approaches: simulation modeling [2-6], statistical modeling [7,8], and control theoretic [9-11]. The results of these modeling studies have shown that the bullwhip effect can be managed with selecting the proper forecasting method and ordering policy [2,7-10], reducing the lead-time [7-10] and increasing the collaboration level [2,5-7,11-14]. Specifically, collaboration in supply chains and smoothing replenishment rules have been the most suggested approaches for mitigating/avoiding the bullwhip effect (Figure 1).

Smoothing Replenishment Rules

Inventory replenishment policies have been recognized as a major cause of the bullwhip effect and thus it has received a significant attention in the bullwhip effect studies [9,11]. However, the majority of the bullwhip effect studies have been considering the periodic review order-up-to (R, S) policy (OUT policy) motivated by its popularity in practice and research [2,7-13]. In this policy, at the end of each review period, the replenishment order is generated to recover the entire gap between target and available levels of inventory position (net inventory + supply line inventory) [11]. Many studies have quantified the bullwhip effect in supply chain models employ the OUT ordering policy proving that the bullwhip effect is guaranteed when this policy is employed irrespective of the forecasting method used and without making any assumptions about the demand process [7-13].

For avoiding the bullwhip effect, extensive research has been focusing on developing and evaluating smoothing replenishment rules that are modified from the traditional periodic review OUT policy with adding proportional controllers to regulate the reaction to demand changes [11]. The proportional controllers of the smoothing OUT replenishment rule are smoothing terms for the gaps between target and current levels of net inventory and supply line inventory. Specifically, in traditional OUT, the order is generated to recover the entire gaps while in smoothing OUT only a fraction of each gap is

recovered. This research stream has shown that the proper tuning of the proportional controllers can eliminate the bullwhip effect [9,11]. However, some studies have shown that dampening the bullwhip effect largely may increase the inventory variance and thus affecting customer service level [9,11,15].

The available smoothing replenishment rules in literature are mainly based on the traditional OUT replenishment rule. Most recently, Costantino et al. [9] have proposed an alternative smoothing inventory replenishment system that relies on control charts and compared to traditional and smoothing OUT ordering policies under different operational settings. This innovative smoothing approach has shown a promising performance in terms of bullwhip effect elimination and inventory stability. Furthermore, it can be applied easily by each supply chain echelon based on the available historical data of incoming orders to each echelon. However, further research is still required in this new research direction [9].

Supply Chain Collaboration

Many studies have explained the benefits that can be gained from collaboration in supply chains and especially for controlling the bullwhip effect [1-2,6,11]. The idea behind supply chain collaboration is to find a global optimal solution for the whole supply chain [16]. Information visibility has been regarded as the first step towards achieving the collaboration in supply chains [16,17]. Previous research has attempted to quantify the value of information sharing in multi-echelon supply chains with focusing mainly on the information sharing of customer demand [2,6-7,11,12,15-19]. However, the majority of the previous studies have been assuming that all partners in the supply chain can access the actual customer demand in the real-time [2,6,15]. This collaboration strategy is known as Information Enriched Supply Chain

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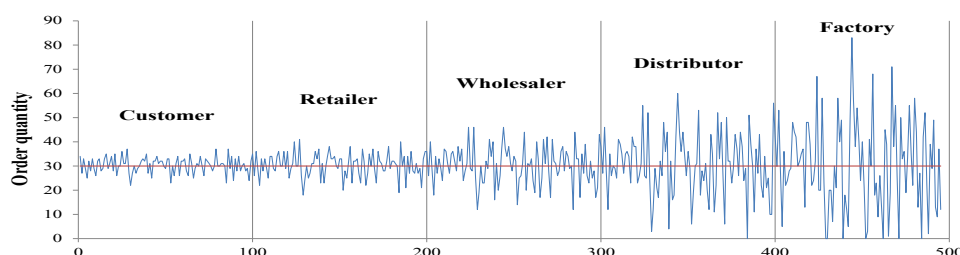


Figure 1: Graphical representation of the bullwhip effect [2,6].

(IESC) in which all partners should invest in technological systems to enable the collaboration in supply chain [11]. Other collaboration strategies that need much effort for implementation such as Vendor Managed Inventory (VMI) and Collaborative Planning, Forecasting and Replenishment (CPFR) have also been evaluated, showing a superior performance compared to traditional supply chain in terms of the bullwhip effect [17-19]. However, it has been noted that the bullwhip literature contains few studies that describe collaboration models that can be easily implemented in supply chains [12].

Most recently, some researchers have proposed coordination mechanisms that can achieve the same role of information sharing but in a decentralized way to be suitable for traditional supply chains that are lacking IT capabilities [5,12,14,18]. This collaboration approach can enable a level of collaboration among supply chain partners through the ordering process, without the need for high implementation effort compared to the other proposed collaboration approaches such as IESC, VMI and CPFR. This new research stream is promising and needs further research directed to the development of easy-to-implement collaboration models and coordination mechanisms. Therefore, the industrial engineering researchers are encouraged to formulate innovative collaboration models and to evaluate them in the context of multi-echelon supply chains in terms of bullwhip effect and inventory stability. Furthermore, the development of coordination mechanisms that combine the power of both information sharing and order smoothing should also be researched [12,15].

Concluding Remarks

The bullwhip effect can be managed in supply chains through improving the operational efficiency and increasing the collaboration level. The available studies have shown that forecasting contributes significantly to the bullwhip effect and therefore many studies have attempted to quantify the impact of the common forecasting methods to provide useful managerial insights on how to control instability propagation in supply chains. However, the literature lacks studies on innovative forecasting systems dedicated to the reduction/elimination of the bullwhip effect without affecting inventory performance [10]. This is a potential future research direction.

Smoothing replenishment rules have been found to be a powerful approach to eliminate the bullwhip effect but it might affect the inventory performance and customer service level. Therefore, there is a need for additional research on the trade-off between the bullwhip effect and inventory stability to guide the supply chain managers on the best practices to improve the supply chain operational performance and customer service level. Furthermore, the available smoothing replenishment rules are mainly based on the traditional OUT ordering rule [9,11,15]. The development of innovative smoothing

replenishments that can be simply applied in supply chains is a promising research direction.

The available studies on collaboration have assumed the presence of high advanced technological systems that can allow the transfer of demand and other important data among supply chain echelons in the real-time. There is a need for innovative collaboration models and coordination mechanisms that can be easily implemented in traditional supply chains without the need for high implementation efforts. Furthermore, the research in this area should focus on showing how shared information can be utilized in planning and inventory control processes across the supply chain.

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